Correlation of Five Wheat Growth Stage Scales Used in the Great Plains

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Contents

Preface

This publication is an outgrowth of a request from the U.S. Department of Agriculture, Agricultural Research Service (USDA-ARS) scientists involved in research to develop wheat yield prediction models. The need was identified for developing the means of converting from one growth stage scale to another to facilitate communications and to evaluate published information.

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L. W. Briggle, USDA-ARS, National Program Staff, Beltsville, Md.

The photographs depicting the Haun scale, provided by J. R. Haun, and the Waldren and Flowerday scale, provided by A. D. Flowerday, appeared in their publication. Drawings depicting growth stages, illustrated in figures 23 to 31, were prepared by G. E. Fischbacher, USDA-ARS, Columbia Plateau Conservation Research Center, Pendleton, Oreg.

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Correlation of Five Wheat Growth Stage Scales Used in the Great Plains

Armand Bauer, Darryl Smika, and Alfred Black[1]

Introduction

Recognition and proper identification of the growth stage of cereal crops at any point during the growing season serves many useful purposes. For example, the effectiveness of herbicides and fungicides can be affected by the growth stage of both the pest and the crop. Usually these pesticides are most effective within a relatively narrow range of plant development. Timing of water and fertilizer application to coincide with specific growth stages can improve the efficiency of both. We have known for some time that a water shortage at anthesis (flowering) of wheat has a greater depressing effect on grain yield than if the shortage occurs at other growth stages (Bauer 1972).

Plant growth stage identification also is useful in agricultural research and education. The impact of weather events or conditions on grain yield differ with the growth stage at which the specific events occur. Each component of grain yield— number of heads per unit area, number of kernels per head, and kernel weight—is in the process of development or determination over a different part of the growing season. Evaluating the impact of the environment on final grain yield may be more precisely assessed if growth stage at the time of stress occurrence is known. As an example, Frank and Bauer (1982) showed that the potential spike (head) size of hard red spring wheat is larger when air temperature during apex initiation (double ridge, which occurs during the 4- to 5-leaf stage) is 10°C than if it is 26°. How the contribution of each yield component to the final yield is affected by the environment at different stages of plant development will require further intensive study.

Several growth stage scales have been developed to designate specific stages of development of wheat and other cereal crops as they progress from emergence, through tillering and jointing, to boot, and heading (fig. 1). These scales vary in degree of detail and in method of numerical or alphabetical designation of growth stage. Also terminology has evolved, designating certain stages[2] such as "jointing," "in-the-boot," "shot blade," and "flag leaf," that is not common to all scales. The availability of several scales differing in detail, method of designation, and descriptive terminology has created a need for a means to convert from one scale to another. It is the purpose of this publication to show the relationship among five scales commonly used in the Great Plains to facilitate conversion from one to another.

The five scales considered are those of Feekes (Large 1954), Robertson (1968), Haun (1973), Zadoks et al. (1974), and Waldren and Flowerday (1979). Other scales exist but were not included. Jensen and Lund (1967) show five growth stages designated as seedling, tillering, jointing, boot, and heading. The scale of Keller and Baggiolini (1954) is an extended Feekes scale, according to Zadoks et al. (1974), in which growth stages are coded by letters. These authors also suggest that the scale of Brouwer (1972) is a recoded Feekes scale. Klepper et al. (1982) proposed a scale quantifying appearance and development of the leaves on the main stem together with appearance of tillers associated with specific leaves of the main stem.

Feekes Scale

This scale, as illustrated and amended by Large (1954), is probably the best known and most widely used of all scales. The numerical notation system is based on morphological change. The stages are numbered from 1 to 11 in the order of appearance, beginning after seedling emergence through grain ripening (fig. 2). The heading and ripening stages are subdivided, and the subdivisions are indicated by numbers in one or two additional columns (table 1). The ripening stages are based on "feel" rather than on visual observation.

Robertson Scale

The alphabetical notation system is based on six phenological events:

Planting (P)—the seed is put in the ground.

Emergence (E)—when it is first possible to see emerged plants.

Jointing (J)—the stage of first internode elongation when the growing point or primordium moves upward from the crown of the young plant. This can be observed only by dissecting plants. This stage usually occurs just before appearance of the fifth leaf.

Heading (H)—stage when the base of the rachis (or head) reaches the same height as the ligule (or base of the shot blade).

Soft dough (S)—when kernels from the central part of the head are still easily deformed when pressed between the fingers, but no "milk" or "liquid" exudes under such pressure.

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[2] Definitions: Jointing—The first node is just visible above the soil surface, heralding stem extension.
In-the-boot—The spike (head, ear) is prominent inside the upper leaf sheath.
Flag leaf—The last leaf developed by the plant.
Shot blade—Same as the flag leaf.

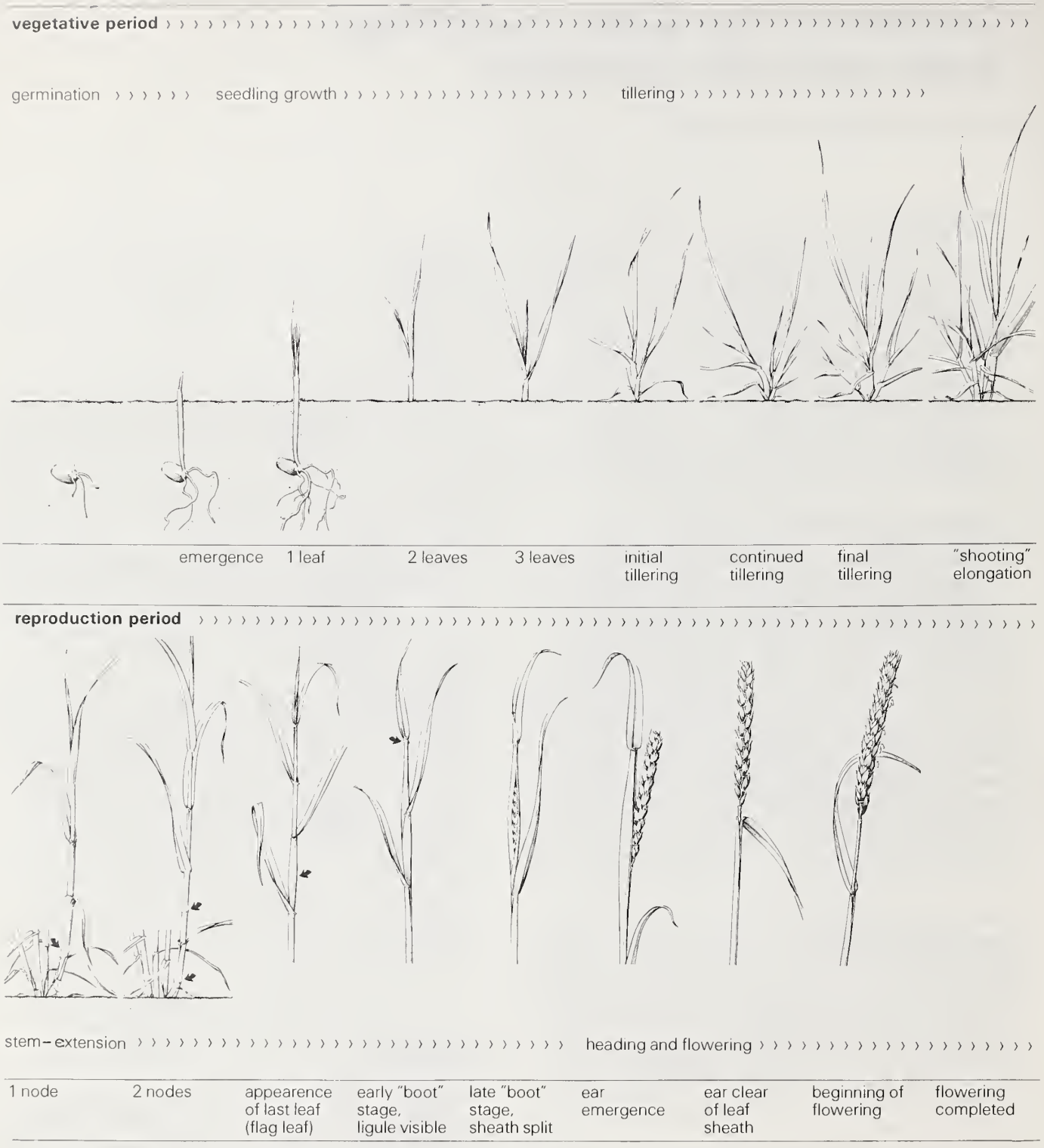

FIGURE —Stages of plant growth and development (Briggle 1980).

Ripe (R)—when it is no longer possible to deform the kernel by pressure between the fingers, but the kernel can still be cut by pressure from the fingernail. On so breaking the kernel open, the interior displays a white, floury appearance.

Haun Scale

The numerical notation system is based on growth units, that is, the leaves produced on the main stem of the plant and four units developing between full expansion of the last (flag) leaf and anthesis (flowering). Each unit is subdivided into decimal fractions beginning with its own appearance and ending with the appearance of the next growth unit. The growth stage is designated by the total number of fully developed units plus the fractional part of the developing unit.

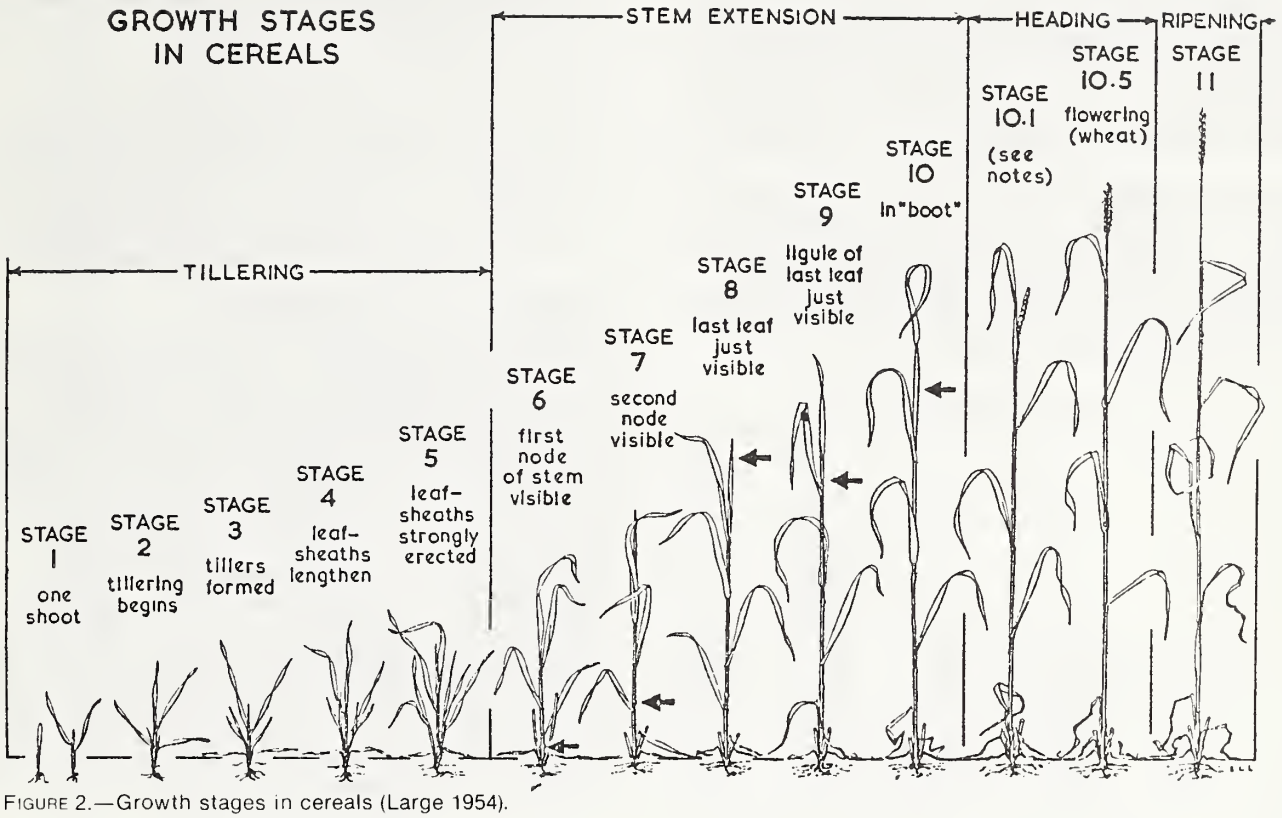

FIGURE 2.—Growth stages in cereals (Large 1954).

Table 1.—Growth stages depicted by Feekes scale in figure 2

Stage	Description
	Tillering
1	One shoot (number of leaves can be added) = 'brairding'.[1]
2	Beginning of tillering.
3	Tillers formed, leaves often twisted spirally. In some varieties of winter wheats, plants may be 'creeping' or prostrate.
4	Beginning of the erection of the pseudo-stem, leaf-sheaths beginning to lengthen.
5	Pseudo-stem (formed by sheaths of leaves) strongly erected.
	Stem extension
6	First node of stem visible at base of shoot.
7	Second node of stem formed; next-to-last leaf just visible.
8	Last leaf visible but still rolled up; ear beginning to swell.
9	Ligule of last leaf just visible.
10	Sheath of last leaf completely grown out; ear swollen but not yet visible.
	Heading
10.1	First ears just visible (awns just showing in barley; ear escaping through split of sheath in wheat or oats).
10.2	Quarter of heading process completed.
10.3	Half of heading process completed.
10.4	Three-quarters of heading process completed.
10.5	All ears out of sheath.
	Flowering (wheat)
10.5.1	Beginning of flowering (wheat).
10.5.2	Flowering complete to top of ear.
10.5.3	Flowering over at base of ear.
10.5.4	Flowering over; kernel watery-ripe.
	Ripening
11.1	Milky ripe.
11.2	Mealy ripe; contents of kernel soft but dry.
11.3	Kernel hard (difficult to divide by thumb-nail).
11.4	Ripe for cutting. Straw dead.

[1] Sprout or spring up from ground; to germinate.

Growth stage of the developing first leaf is a fraction of 1, the designation depending upon the extent of development (fig. 3). After full expansion, marked by the appearance of the second leaf, the growth stage designation is 1.0. As the second leaf develops, the growth stage designation is 1 plus a decimal fraction, determined by the approximate length of the second leaf relative to the first. Growth stage designation in which leaves are the growth units is illustrated with the appearance and development of the 7th leaf (fig. 4).

Flag leaf extension is the first of the four recognized growth units following expansion of the flag leaf (fig 5). During flag leaf extension, the growth stage designation is the number of leaves produced on the main stem plus a decimal fraction, determined by the extent of flag leaf extension relative to the length of the last leaf formed before the flag leaf.

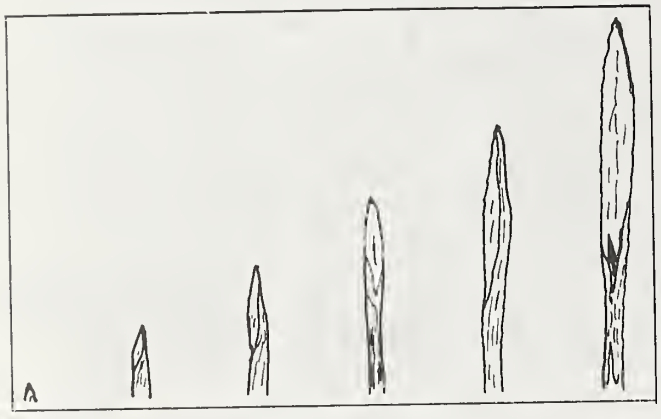

FIGURE 3.—Development of the first leaf of wheat (Andox). At 0.0, the leaf is emerging from the cloeoptile and, at 1.0, the second leaf is just visible in the rolled part of the first leaf. The intermediate designations are 0.2, 0.4, 0.6, and 0.8.

FIGURE 4.—Development of other leaves (leaf 7 in this example) in 0.1 units, from 6.0 to 6.9. The unit designation is determined by the approximate length of the seventh leaf (on left) relative to the length of the sixth leaf (on right).

Flag leaf extension is followed by enlargement of the boot (fig. 6). Boot stage is completed when the spike (head) begins to emerge. The growth stage designation is one more than the number of leaves produced by the main stem plus a decimal fraction, determined by the position of the spike in the upper leaf sheath.

Spike emergence (heading) follows completion of the boot stage (fig. 7). The growth stage designation is two more than the number of leaves produced on the main stem plus a decimal fraction, determined by the relative portion of the spike that has advanced beyond the collar of the flag leaf.

The last growth unit, culm (stem) elongation, begins as the lowest portion of the spike has cleared the collar of the flag leaf (fig. 8). The growth stage designation is three more than the number of leaves produced on the main stem plus a decimal fraction, determined by the length of the stem relative to the length of the flag leaf. Anthesis (flowering) terminates this stage.

Zadoks-Chang-Konzak Scale

This 2-digit numerical notation system is coded for 10 principal growth stages (table 2), the first number in the 2-digit system, and as many as 10 secondary growth stages within each principal growth stage (table 3), the second number in the 2-digit system. Except for the germination stage coded 0, the onset and termination of the principal growth stages for cereals, not including rice, are described as by the Feekes scale, although the numerology differs. The secondary growth stage designations, indicated by numbers 0 to 9, provide for refinement within a principal growth stage. For example, the growth stage designation 13 means three leaves are present on the main stem during the seedling stage. During principal growth stage 2, the second digit indicates the number of tillers on the plant, while during stem elongation, principal growth stage 3, the second digit refers to the number of nodes detectable on the stem.

Table 2.—Principal growth stages of the Zadoks-Chang-Konzak scale

1-Digit code	Description
0	Germination
1	Seedling growth
2	Tillering
3	Stem elongation
4	Booting
5	Inflorescence (spike) emergence
6	Anthesis
7	Milk development
8	Dough development
9	Ripening
T	Transplanting and recovery (rice only)

Waldren-Flowerday Scale

The numerical notation system is based on an 11-point scale developed primarily for winter wheat. The stages are identified by morphological changes (table 4). Elements of plant characteristics defining specific growth stages are illustrated and described in figures 9 through 22.

Table 3.—Secondary growth stage designations of the Zadoks-Chang-Konzak scale

2-Digit code	General description
	Germination
00	Dry seed
01	Start of imbibition
02	___
03	Imbibition complete
04	___
05	Radicle emerged from caryopsis
06	___
07	Coleoptile emerged from caryopsis
08	___
09	Leaf just at coleoptile tip
	Seedling growth
10	First leaf through coleoptile
11	First leaf unfolded
12	2 leaves unfolded
13	3 leaves unfolded
14	4 leaves unfolded
15	5 leaves unfolded
16	6 leaves unfolded
17	7 leaves unfolded
18	8 leaves unfolded
19	9 or more leaves unfolded
	Tillering
20	Main shoot only
21	Main shoot and 1 tiller
22	Main shoot and 2 tillers
23	Main shoot and 3 tillers
24	Main shoot and 4 tillers
25	Main shoot and 5 tillers
26	Main shoot and 6 tillers
27	Main shoot and 7 tillers
28	Main shoot and 8 tillers
29	Main shoot and 9 or more tillers
	Stem elongation
30	Pseudo stem erection
31	1st node detectable
32	2nd node detectable
33	3rd node detectable
34	4th node detectable
35	5th node detectable
36	6th node detectable
37	Flag leaf just visible
38	___
39	Flag leaf ligule/collar just visible
	Booting
40	___
41	Flag leaf sheath extending
42	___
43	Boots just visibly swollen
44	___
45	Boots swollen
46	___
47	Flag leaf sheath opening
48	___
49	First awns visible

2-Digit code	General description
	Inflorescence emergence
50	First spikelet of inflorescence just visible
51	
52	
53	¼ of inflorescence emerged
54	
55	½ of inflorescence emerged
56	
57	¾ of inflorescence emerged
58	Emergence of inflorescence completed
59	
	Anthesis
60	
61	Beginning of anthesis
62	___
63	___
64	
65	Anthesis half-way
66	___
67	___
68	
69	Anthesis complete
	Milk development
70	___
71	Caryopsis water ripe
72	___
73	Early milk
74	___
75	Medium milk
76	___
77	Late milk
78	___
79	___
	Dough development
80	___
81	___
82	___
83	Early dough
84	___
85	Soft dough
86	___
87	Hard dough
88	___
89	___
	Ripening
90	___
91	Caryopsis (kernel) hard (difficult to divide by thumb-nail)
92	Caryopsis hard (can no longer be dented by thumb-nail)
93	Caryopsis loosening in daytime
94	Over-ripe, straw dead and collapsing
95	Seed dormant
96	Viable seed giving 50 percent germination
97	Seed not dormant
98	Secondary dormancy induced
99	Secondary dormancy lost

Discussion

The Haun and Zadoks-Chang-Konzak scales provide for greater descriptive detail than other scales because these track the appearance of leaves on the main stem, assigning a number to each leaf (figs. 23, 24, 25, 26, 27, 28). This detail is especially advantageous for developing crop calendars. In addition, the Haun scale provides for designation detail during the development of each leaf on the main stem and four growth units following expansion of the flag leaf.

Table 4.—Stages and identifying characteristics of the Waldren-Flowerday scale

Stage	Description
0	Emergence of coleoptile.
1	Crown is visible, tillers (branches) develop. Each branch will have produced 2 or 3 leaves.
1.5	The collars of 1 or more of the lower leaves are visible.
2	Leaf sheaths elongate and form a false stem. From 5 to 7 leaves are visible on each branch
3	Culm elongation. First internode visible (jointing).
3.5	The second node is visible on the main branches and the first node on secondary branches.
4	Tip of flag leaf visible on the main branch.
4.5	The flag leaf collar is visible, and the inflorescence is beginning to swell.
5	Peduncle elongates (boot) and inflorescence emerges (heading).
6	Flowering (anthesis).
7	Anthesis complete. Grain filling begins. Lower leaves and culm turn from green to gold or brown.
7.5	Grain is milky to soft dough.
8	Grain is stiff dough. Flag leaf has lost all green color.
9	Ripening. Grain hard but will not crack. Inflorescence has lost all green color. Uppermost node still green.
10	Maturity. Grain cracks and is easily separated from chaff.

FIGURE 5.—Extension of the flag leaf, x.2, x.4. x.6, x.8, and 1 + x.0 units. This phase is completed with the first signs of swelling of the boot. x refers to the number of the flag leaf.

FIGURE 6.—Enlargement of the boot, 1 + x.2, 1 + x.4, 1 + x.6, 1 + x.8, and 2 + x.0 units. This phase is completed when the spike (head) begins to emerge. x refers to the leaf number of the flag leaf.

FIGURE 7.—Emergence of the spike, 2 + x.2, 2 + x.4, 2 + x.6, 2 + x.8, and 3 + x.0 units. x refers to the leaf number of the flag leaf.

FIGURE 8.—Elongation of the culm. 3 + x.2, 3 + x.4, 3 + x.6, 3 + x.8, and 4 + x.0 units. x refers to the leaf number of the flag leaf.

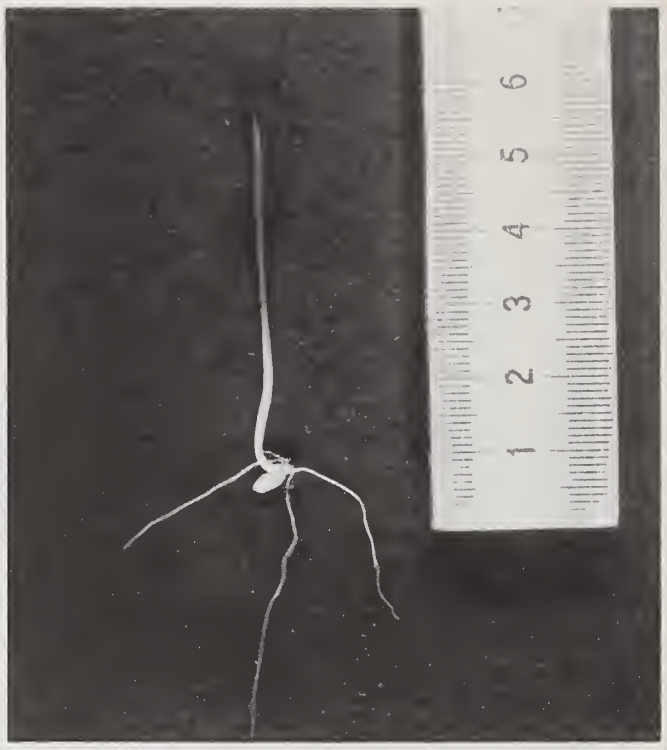

FIGURE 9.—Stage 0. Seedling emerges from soil, and first leaf emerges from the coleoptile (sheath).

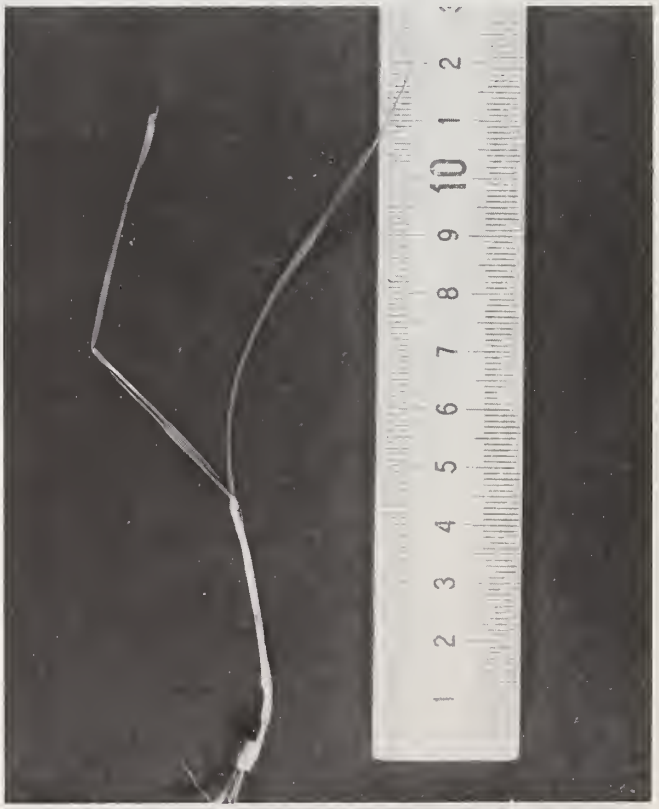

FIGURE 10.—Stage 1. Crown becomes visible as a small node-like swelling at the base of the coleoptile and tiller development begins.

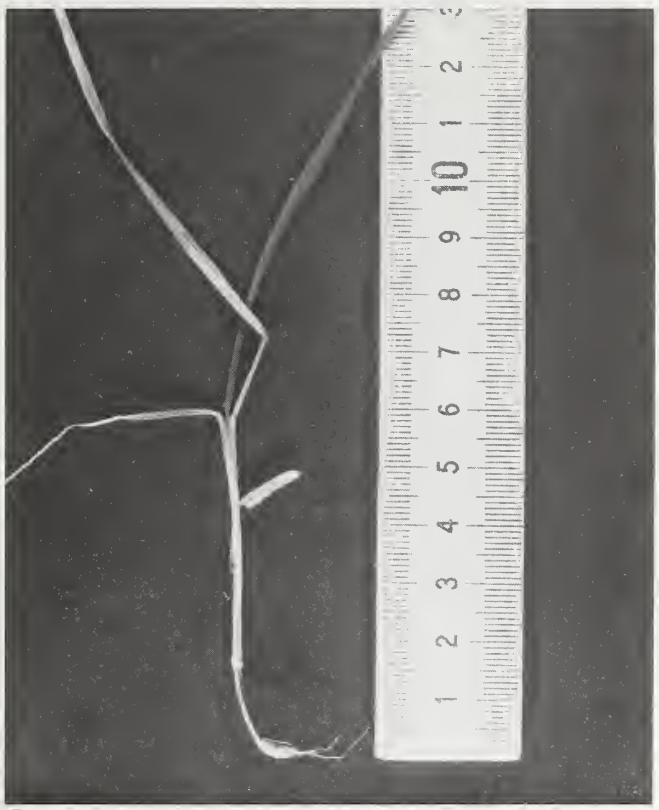

FIGURE 11.—Stage 1.5. Collars at the base of one or more leaf blades become visible.

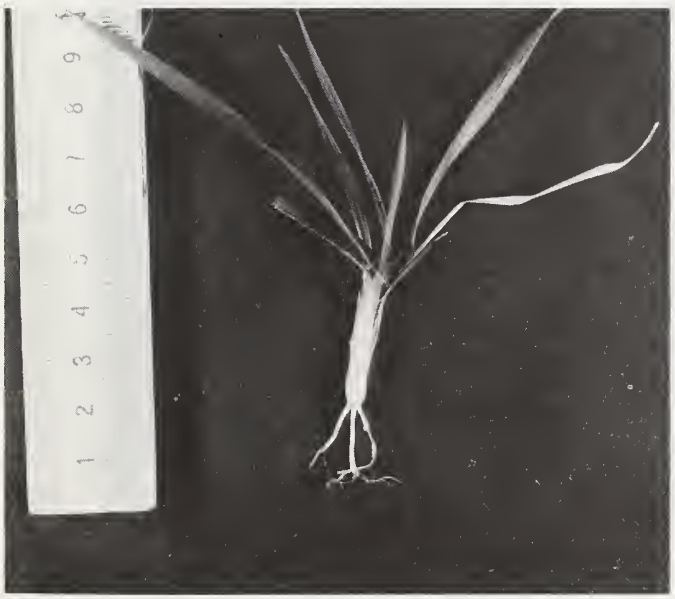

FIGURE 12.—Stage 2. Leaf sheaths elongate to produce a false stem.

FIGURE 13.—Stage 3. First internode begins to elongate on main or largest culm (jointing).

FIGURE 14.—Stage 3.5. Second internode and inflorescence (head) visible on main or longest culm and first internode visible on secondary tillers.

FIGURE 15.—Stage 4. Flag (uppermost) leaf becomes visible.

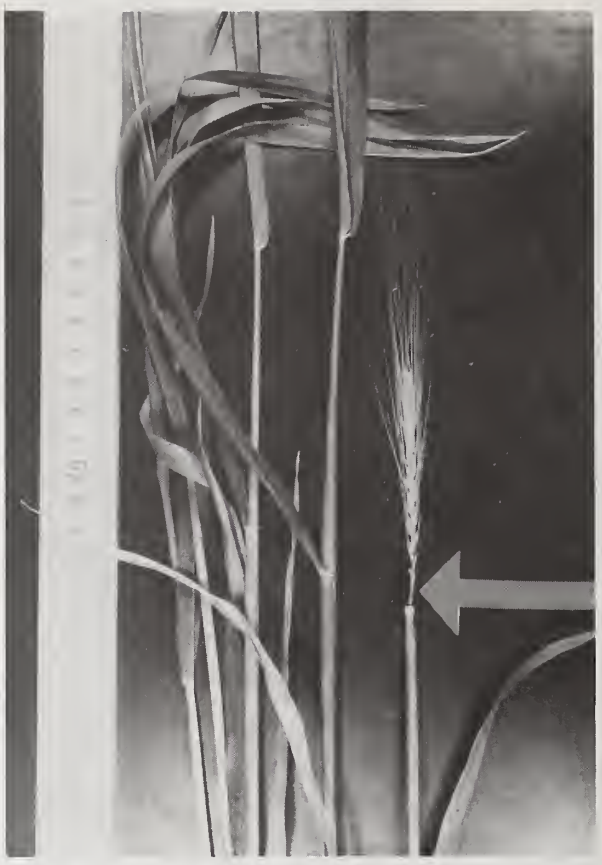

FIGURE 17.—Stage 5. Peduncle at base of head begins to elongate. Inflorescence emerges during this stage (heading).

FIGURE 16.—Stage 4.5. Collar of flag leaf, including auricles and ligules, is visible. Head is beginning to swell the flag leaf sheath (boot stage).

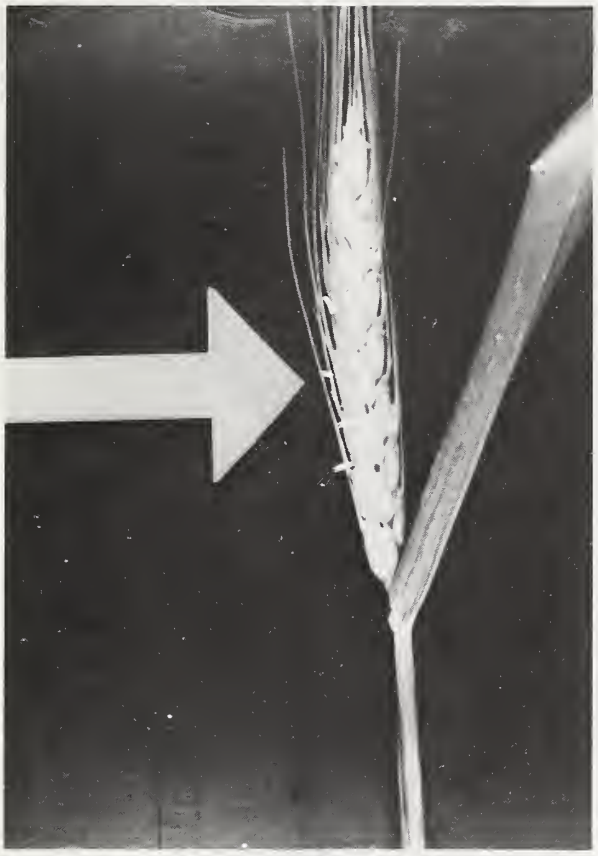

FIGURE 18.—Stage 6. Flowering (anthesis). First anthers emerge from head.

FIGURE 20.—Stage 8. Grain a stiff dough. Stage begins when flag leaf has lost all green color but inflorescence is still green.

FIGURE 19.—Stage 7. Anthesis complete. All anthers have emerged. Grain filling begins. Lower leaves and culm begin to turn color.

FIGURE 21.—Stage 9. Ripening. Grain hard but will not crack. Stage begins when inflorescence loses all green color. Arrow points to uppermost node, which is still green.

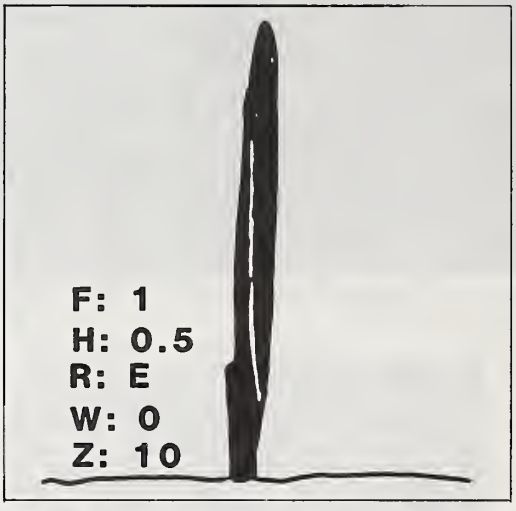

FIGURE 23.—Seedling is emerging. (Growth stage scale designations are: F = Feekes, H = Haun, R = Robertson, W = Waldren-Flowerday, and Z = Zadoks-Chang-Konzak.)

FIGURE 22.—Stage 10. Maturity. Grain cracks and is easily separated. No green color left.

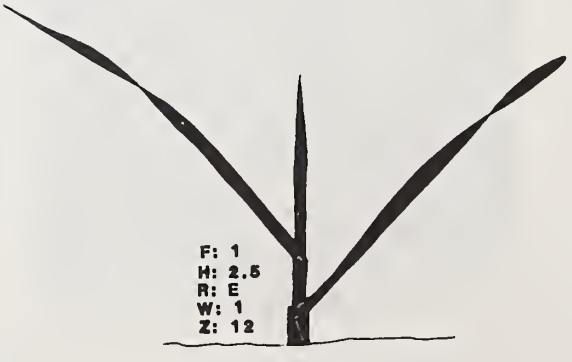

FIGURE 24.—Two expanded leaves on the main stem and the third leaf is developing.

FIGURE 25.—Three expanded leaves on the main stem and the fourth is developing (dark leaves). A leaf tiller (light leaf) is developing in the axil of the first leaf of the main stem. A coleoptile tiller is developing next to the main stem.

FIGURE 26.—Five expanded leaves on the main stem and the sixth is developing (dark leaves). Three leaf tillers (light leaves) are present.

FIGURE 27.—Six expanded leaves on the main stem and the seventh is developing (dark leaves). Three leaf tillers (light leaves) are present.

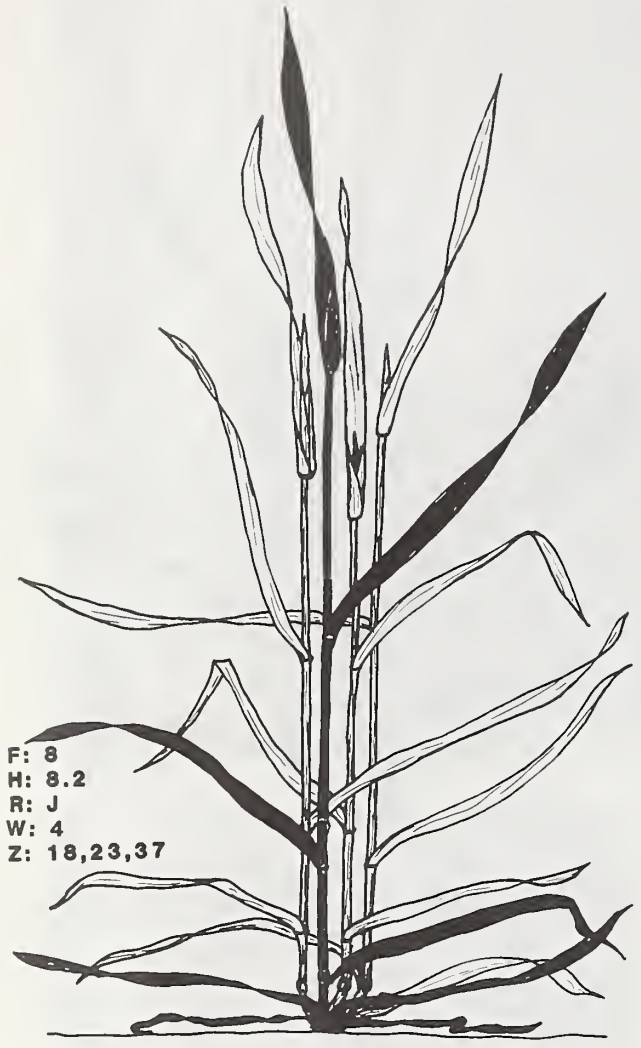

FIGURE 28.—Eight expanded leaves on the main stem and the ninth is developing (dark leaves). Of the three leaf tillers, one is developing a sixth leaf, one a fifth leaf, and one a fourth leaf.

In the Haun scale, the numerical designations assigned to flag leaf extension, enlargement of the boot (fig. 29), heading (fig. 30), and spike extension (fig. 31) are cultivar dependent because not all cultivars produce the same number of leaves on the main stem. Hard red spring and durum wheats normally produce 8 leaves and winter wheat usually 11. However, one hard red spring wheat in our cultivar trials produced only 7 leaves on the main stem, and Betty Klepper (private communication) has observed as few as 8 and as many as 13 leaves on winter wheat grown in the Palouse Region of Oregon and Washington. Thus the scale may not be identical over the entire range of development among cultivars within a wheat ciass. The Haun scale, furthermore, does not provide for designation of stages following anthesis, nor does it consider the number or stage of development of tillers as does the Zadoks-Chang-Konzak scale. A problem arises using either the Haun or Zadoks-Chang-Konzak scale when the infrequent observer fails to recognize that the first, or first and second, leaves may no longer be present on the main stem and, hence, not counted.

The 2-digit Zadoks-Chang-Konzak scale provides more detail about plant development during the tillering and stem elongation stages than the Haun scale, but it lacks some of the detail of the Haun scale in designating the development stage of leaves on the main stem. Also, the numerical designation during seedling growth for a plant having more than nine leaves on the main stem or during tillering for a plant with more than nine tillers is the same as the plant with nine leaves or nine tillers. Hard red spring and durum wheats usually will not produce more than an average of three tillers per plant in a normal population resulting from a seeding rate of about 2.5 million viable seeds per hectare, but, winter wheat, seeded at about 30 to 50 percent of this spring wheat rate, will produce as many as 15 tillers per plant. The advantage of the in-depth detail provided by the Zadoks-Chang-Konzak scale is illustrated with a seedling with three leaves and one tiller. This can be coded 13 for leaf number or coded 21 for tiller number. Similarily, plants with three-fourths of the heads emerged are coded 57 and, if anthesis has begun in those fully emerged, the code is 61.

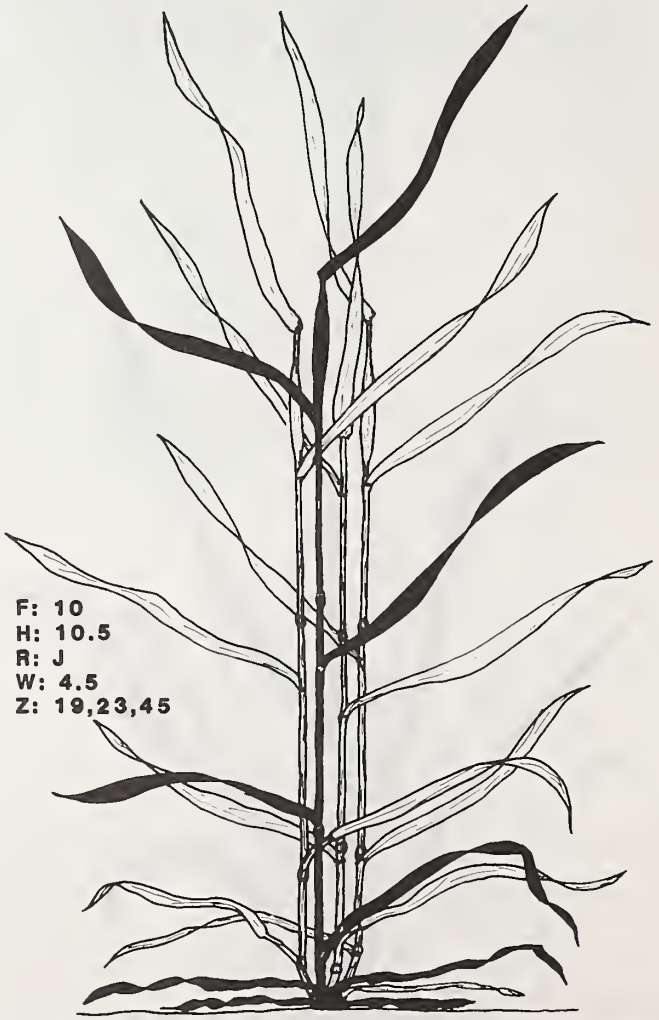

FIGURE 29.—Nine fully expanded leaves on the main stem (dark leaves). The flag leaf (ninth leaf) has been extended. The inflorescence (boot) is prominent in both the main stem and tillers (light leaves). Frequently the lower two leaves of the main stem have been sloughed off by this stage.

FIGURE 30.—Nine fully expanded leaves on the main stem (dark leaves). The flag leaf has been extended. The awns of the head (spike, ear) are emerging from the collar of the flag leaf, marking completion of the "boot" stage and the beginning of heading. The tillers (light leaves) are in the "boot" stage, less advanced in development than on the main stem.

The Feekes and the Waldren-Flowerday scales have the desirable feature of constant numeral designations, irrespective of number of leaves or tillers developed by the wheat plants. However, the Feekes scale appears somewhat ambiguous for early growth stages, for we find it difficult to distinguish between successive stages from 4 through 6 in both spring and winter wheats (figs. 26, 27). This same difficulty appears to be associated with the Waldren-Flowerday scale. The Feekes scale also is lacking in efficiency for use in data processing and for computer storage and retrieval (Loegering as cited by Zadoks et al. 1974).

Of the scales included, Robertson's is the least definitive of the five. As presented, it appears to lack sufficient precision and detail for many purposes.

Comparisons of growth stage designations among the five scales are presented in table 5. The number of tillers is unspecified. The designation for the Haun scale is for cultivars with eight leaves. With fewer or more than eight leaves, some of the designations listed in the table under the Haun scale will differ from those listed.

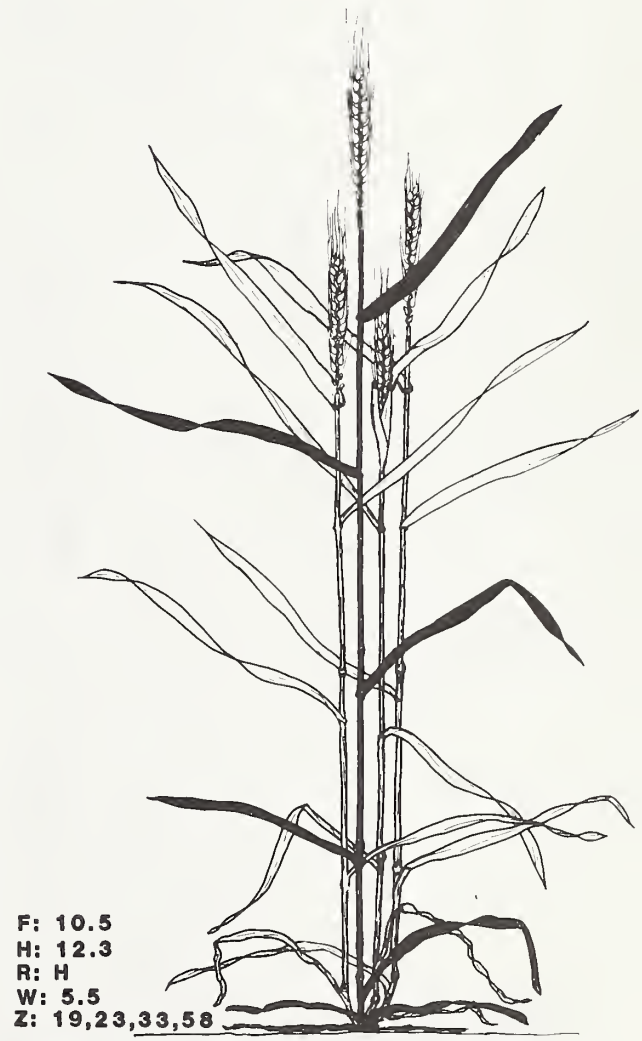

FIGURE 31.—Nine fully expanded leaves on the main stem (dark leaves). The flag leaf has been extended. Boot stage is completed. The head has emerged from the collar to complete the heading stage. Head extension is occurring on the main stem and two of the three tillers. On the third tiller the head has not cleared the collar, hence it is in the heading stage.

Table 5.— Correlation of five wheat growth stage scales[1]

Description	Scale: Robertson	Waldren-Flowerday	Zadoks-Chang-Konzak	Haun	Feekes
Planting germination	(P)		00		
Emergence	(E)	0	09	0.0	
			10	0.2	1
Seedling growth				0.4	
				0.6	
				0.8	
				1.0	
			11	1.2	
				1.4	
			12	1.6	
				1.8	
				2.0	
		1		2.2	
				2.4	
			13	2.6	
				2.8	
Tillering		1.5	20	3.0	2
				3.2	
				3.4	
			14[2]	3.6	3
				3.8	
				4.0	
				4.2	
				4.4	4
			15[2]	4.6	
				4.8	
		2		5.0	5
				5.2	
			30	5.4	
Stem extension	(J)	3	16[2] 31	5.6	6
				5.8	
				6.0	7
				6.2	
				6.4	
			17[2]	6.6	
				6.8	
		4	37	7.0	8
				7.2	
				7.4	
			18[2]	7.6	
				7.8	
		4.5	39	8.0	9

Description	Scale: Robertson	Waldren-Flowerday	Zadoks-Chang-Konzak	Haun	Feekes
Flag leaf extension			41	8.2	
				8.4	
				8.6	9
				8.8	
				9.0	
Boot		5	43	9.2	10
				9.4	
			45	9.6	
				9.8	
			47		
			49	10.0	
Heading	(H)	5	50	10.2	10.1
				10.4	
				10.6	
				10.8	
			59	11.0	10.5
Spike extension				11.2	
Anthesis		6	60	11.4	10.5.1
			65	11.5	10.5.2
				11.6	10.5.3
		7	69		10.5.4
Milk	(S)		71		
Dough		7.5	73-77		11.1
		8	83-85		11.2
		9	87-91		11.3
Ripe	(R)	10	92		11.4

[1] Based on 8 leaves on the main stem.
[2] Denotes number of leaves on the main stem and no tillers.

References

Bauer, Armand. 1972. Effect of water supply and seasonal distribution on spring wheat yields. North Dakota Agric. Exp. Sta. Bull. 490.

Briggle, L. W. 1980. Origin and botany of wheat, p. 6-13. *In* Wheat, Documenta CIBA-Geigy. CIBA-Geigy Ltd., Basel, Switzerland.

Brouwer, W. 1972. Handbuch des Speziellen Pflanzenbaues I. Paul Parey, Berlin. (cited by Zadoks et al. 1974).

Frank, A. B., and A. Bauer. 1982. Effect of temperature and fertilizer N on apex development in spring wheat. Agron. J. 74:504-509.

Haun, J. R. 1973. Visual quantification of wheat development. Agron. J. 65:116-119.

Jensen, L. A., and H. R. Lund. 1967. How cereal crops grow. North Dakota Agric. Coop. Ext. Bull. No. 3.

Keller, C., and M. Baggiolini. 1954. The stades reperes dans la vegetation du ble'. Rev. Romande d'Agr. 10:17-20. (cited by Zadoks et al. 1974; Briggle 1980).

Klepper, Betty, R. W. Rickman, and C. M. Peterson. 1982. Quantitative characterization of vegetative development in small cereal grains. Agron. J. 74:789-792.

Large, E. C. 1954. Growth stages in cereals. Plant Pathol. 3:128-129.

Newman, J. E., and J. B. Beard. 1962. Phenological observations: the dependent variable in bioclimatic and agrometeorological studies. Agron. J. 54:399-403.

Robertson, G. W. 1968. A biometeorological time scale for a cereal crop involving day and night temperatures and photo-period. Int. J. Biometeorol. 12:191-223.

Waldren, R. P., and A. D. Flowerday. 1979. Growth stages and distribution of dry matter, N, P, and K in winter wheat. Agron. J. 71:391-397.

Zadoks, J. C., T. T. Chang, and C. F. Konzak. 1974. A decimal code for the growth stages of cereals. Weed Res. 14:415-421.

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